Notes on *Actias dubernardi* (Oberthür, 1897), with description of the early instars (Lepidoptera: Saturniidae)

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Abstract: An overview of the knowledge on *A. dubernardi* (Oberthür, 1897) is given. The early instars are described and notes on behaviour and foodplants are mentioned; the larvae have silver spots and a thoracic warning pattern. All preimaginal instars, living moths and male genitalia structures are figured in colour. First records of the species from Myanmar are mentioned. The results of some recent phylogenetic studies concerning the arrangement of the genera *Actias* Leach *in* Leach & Nodder, 1815, *Argema* Wallengren, 1858 and *Graellsia* Grote, 1896 are briefly discussed.

Anmerkungen zu *Actias dubernardi* (Oberthür, 1897) mit Beschreibung der Präimaginalstadien (Lepidoptera: Saturniidae)

Zusammenfassung: Es wird eine Übersicht über die bisherigen Kenntnisse über die chinesische *Actias dubernardi* (Oberthür, 1897) gegeben. Die Präimaginalstadien werden beschrieben, Beobachtungen zum Verhalten und zu den Raupenfutterpflanzen werden dargestellt und eine Übersicht zur Zuchtdauer gegeben. Die älteren Raupen zeichnen sich durch silbrige Flecken und ein thorakales schwarzrotes Warnband aus. Sämtliche Präimaginalstadien, lebende Falter sowie die männlichen Genitalstrukturen werden farbig abgebildet. Erstnachweise der Art aus Myanmar werden angegeben. Die Ergebnisse einiger phylogenetischer Studien der letzten Jahre werden bezüglich der Einordnung der Gattungen *Argema* Wallengren, 1858 und *Graellsia* Grote, 1896 zu *Actias* Leach *in* Leach & Nodder, 1815 kritisch diskutiert.

Introduction

Actias dubernardi was described by Oberthür (1897) in the genus *Tropaea* Hübner, 1819 ("1816") based on two ♂ syntypes from "Tsekou" of the Tibet-Yunnan borderline, collected by the missionary P. Dubernard. This locality was specified by Schintlmeister (1992: 213) as: Yunnan province, ca. 28°0′ N, 98°5′ E, a missionary station at the Mekong river, 2285 m. The ♀ from "Leou-Fang" cited within the original description was explicitely excluded from the type series by Oberthür himself as he could not classify it definitely with the species.

In 1913, Watson described a new (probably monobasic) genus *Euandrea* with type species *A dubernardi,* mainly due to different lengths of certain veins of the wings and somewhat longer antennae in comparision to the genus *Sonthonnaxia,* described in the same paper. The genus was named in honour of Ernst André, Macon. Only Schüssler (1936: 54) mentioned a further species, *A. rhodopneuma* Röber, 1925, as second member of this genus (cited by him as a subspecies of *A. dubernardi;* the junior subjective synonym of *A. rhodopneuma, A. distincta* (Niepelt, 1932), was cited in the same genus at full species rank). Packard (1914: 180) mentioned *Euandrea* alrady at subgeneric status, Bouvier (1936: 253) and Testout (1941: 152) in the genus *Argema* Wallengren, 1858, and in more recent literature (e.g. Mell 1950, Zhu & Wang 1983, 1993, 1996, Nässig 1991, 1994, D'Abrera 1998, Morishita & Kishida 2000, Ylla et al. 2005) it was listed as junior subjective synonym of *Actias* Leach *in* Leach & Nodder, 1815.

Until about 10 years ago, the species was very rare in western collections, but with further economic opening of PR China more and more material from this country could be obtained, and eventually also some ova were received directly from China. According current knowledge the species is not as rare as believed earlier; in collections from medium altitudes from April to August specimens are found regularly. Obviously the species is common in southern parts of China. So far, *A. dubernardi* was recorded from the Chinese provinces of Yunnan, Sichuan, Gansu, Shaanxi, Hubei, Anhui, Guizhou, Hunan, Guangxi, Guangdong, Hainan, Jiangxi, Fujian, and Zhejiang (Zhu & Wang 1983, 1993, 1996, Guo et al. 1989, Wang 1992, Morishita & Kishida 2000, Renner et al. 2006; specimens in the author's collection). Only most recently, Langer, Löffler and the author carried out an expedition to northeastern Myanmar (formerly Burma), Kachin state, and collected as first records for this country *A. dubernardi* in late May 2006 frequently alongside the Yunnan borderline at altitudes from 1640 to 1700 m. ♂♂ were found at light around midnight, while ♀♀ were collected around 1:30 h.

A record from northern Vietnam mentioned by Peigler *in* Nässig (1994: 345), a single ♂ in Los Angeles County Museum with data "N. Vietnam, Ng Yuk Ming, 4. viii. 1982" is the only record for this country. Although intensively collected in recent years in this area, no further specimens and also no records in literature were found (compare, e.g., Candèze 1927, de Joannis 1928–1931). The record from India, "Nagaberge", cited by Mell (1935: 363), most likely refers to a misidentified specimen of the superficially similarly coloured *A. rhodopneuma*.

Specimens were, e.g., figured in the original description by Oberthür (1897) and by Jordan (1911), Bouvier (1936), Zhu & Wang (1983, 1996), Morishita & Kishida (2000), and Ylla et al. (2005), a full-grown larva so far only by Ylla et al. (2005) and by Haxaire (2005), and ♂ genitalia structures first by Testout (1946).

[1] 13th contribution to the Saturniidae fauna of China (12th contribution: Naumann & Löffler 2005: Notes on the genus *Saturnia* Schrank, 1802, with description of a new species (Lepidoptera: Saturniidae). — Nachrichten des Entomologischen Vereins Apollo, Frankfurt am Main, N.F. **26** (4): 169–176).

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In the following the larval instars are described, and notes are provided on phylogenetic ideas about the species, resulting from larval habitus and behaviour and from imaginal comparision within the genus *Actias*.

Description of the early instars

Ovum (Fig. 1): Quite large for the genus, flattened ovoid, ca. 2.6 mm × 1.55 mm × 1.3 mm. It is of dark greyish white colour. Eggs are fixed separately with the flattened side on needles of the foodplant. A single reared ♀ deposited only 96 eggs in total. Figured are eggs from second generation, reared in Germany from the original stock.

L_1 (Figs. 2, 3, 4): Freshly hatched 5.5–6.0 mm long, almost completely of black ground colour, only scoli, anal prolegs and plate of ochreous yellow colouration, which also become dark after around 30 minutes. During progression of the instar, the colour becomes lighter, finally becoming an orange red ground colour. Head capsule shining dark brown, there appears a dark grey dorsal longitudinal band from second thoracic to seventh abdominal segment, a grey latitudinal posterior dorsal portion on the first thoracic segment, and two longitudinal bands of black dots dorsal and ventral of the dorsolateral scoli from second thoracic to eighth abdominal segments. Bristles on all scoli black, there is a fused central dorsal scolus on eighth abdominal segment. Thoracic legs black, abdominal prolegs with small lateral dark dot.

Larvae rest at the reddish brown bases of the whorls, for feeding they climb the pine needles to the top and return from there to the inner parts of the whorls. Moulting takes place on the conifer's needles.

L_2 (Figs. 5, 6): Freshly moulted about 9.0 mm long, with minor changes to appearance of late first instar. The black lateral ornamentation is now more intensive, the white spiracles easily visible inside the dark areas, the head capsule and thoracic legs now reddish brown. The dark dorsal portion on the first thoracic segment has now disappeared, as well as the markings on abdominal prolegs, the bristles of all scoli black, only the longer dorsal ones of second and third thoracic segment with white tip. Moulting from now on takes place on small twigs.

L_3 (Figs. 7, 8, 9): Freshly moulted about 14.0 mm long, now with major changings in pattern and colour. The fresh moulted larva is now of reddish colour with yellowish green scoli, getting completely light green after a few hours. Head capsule and thoracic legs now shining reddish brown, abdominal and anal prolegs and ventral side of the larva orange brown. The whole surface of the cuticula is covered with small white granules which partly are bases for short white setae. All scoli with black bristles, the dorsal ones with one additional central white hair which is longest, 5–6 mm, on second and third thoracic segments, all scoli of the type "Stechborstenscolus" (cf. Nässig 1989). All scoli — dorsal, dorsolateral, and lateral — aside of the dorsal thoracic ones have a lateral silver base which gleams sometimes also in a golden or greenish mother-of-pearl-like fashion. In combination with the greenish white spiracles with dark green surrounding, those light spots display a ring-like pattern on each segment. Between dorsal parts of 2nd and 3rd thoracic segment now a typical colourful ring structure comes up: There is a stripe, proximally starting white, then black, and finally red, warning potential predators. This stripe becomes obvious when the larva is disturbed and turns the head down. In normal resting position this structure is visible as a black stripe, similar to a second and more slender one between third thoracic and first abdominal segment.

L_4 (Figs. 10, 11, 12, 13): Freshly moulted 18.0 mm long, now again with minor changings to prior instar. All pattern elements now larger and more intensive, ground colour darker green. Dorsal scoli of first to 7th and 9th abdominal segments now without any black bristles, they bear only long ochreous white hairs; similar are all dorsolateral scoli of thoracic and abdominal segments, they are almost completely green with light tip. The central hair of the 2nd and 3rd thoracic scolus is longest, about 8 mm long, others only little shorter. While the "metallic" pattern is obvious on all abdominal segments (here each dot 1.5–1.8 mm broad), the second and third thoracic scoli, the lateral scoli and a row of ventrolateral rounded small scoli on the thoracic segments and the first abdominal segment show a very small silver spot each only. In the whole abdominal area there are, in the subspiracular row, silver drop-like spots, while the spiracles are of creamy colour. On each segment scoli, spots and spiracles are connected by a light band, and a second white band appears intersegmental. The abdominal prolegs now have a small lateral black dot. From this instar on the larvae can produce sound with their mandibles when disturbed. In addition the colourful alarming ring structure on thoracic segments is still visible (compare Figs. 11, 12).

L_5 (Figs. 14, 15, 16): Freshly moulted 26 mm long, with few changes. Silver spots on dorsal and dorsolateral scoli again larger, covering their whole lateral surface. The dorsal abdominal scoli have now very short black bristles, and the larva feels a little urticating on human skin when touching this structure. Lateral scoli round, in some larvae now more golden than silver. All white granules now with longer white setae, hairs on the scoli are now longer as well. The white band which connects the scoli and the creamy spiracles is more intensive, the inter-

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Plate 1: *Actias dubernardi*. **Fig. 1:** Ova. **Fig. 2:** Larva in L_1, head, freshly hatched. **Fig. 3:** Larva in L_1, lateral view. **Fig. 4:** Larva in L_1, dorsal view. **Fig. 5:** Larva in L_2, lateral view. **Fig. 6:** Larva in L_2 before moulting, lateral view. **Fig. 7:** Larva in L_3, freshly moulted. **Fig. 8:** Larva in L_3, lateral view. **Fig. 9:** Larva in L_3, thorax details. **Fig. 10:** Larva in L_4, lateral view. **Fig. 11:** Larva in L_4, head in resting position. **Fig. 12:** Larva in L_4, head in position after disturbance. **Fig. 13:** Larva in L_4, details of abdomen. **Fig. 14:** Larva in young L_5, lateral view. **Fig. 15:** Larva in fullgrown L_5, lateral view. **Fig. 16:** Larva in L_5, dorsal view. — Photographs author.

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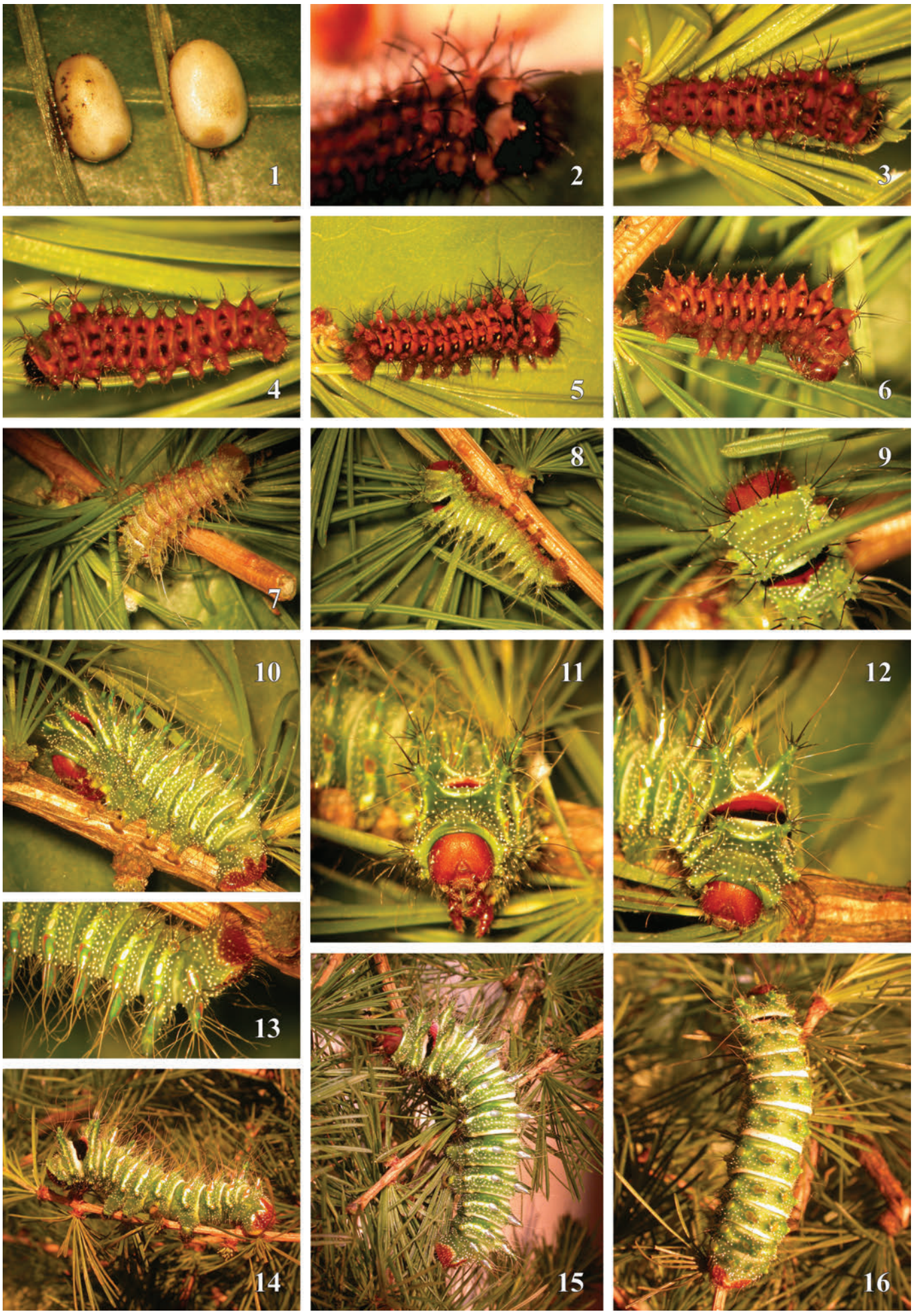

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segmental white band not divided into two portions between each segment. The black and red alarming thoracic band is even more intensive now, as well as the produced sound gets louder. The larvae change the ground colour to a dark green before spinning a cocoon.

Cocoon and pupa (Figs. 18, 19): The quite hard, dark brown cocoon with a homogenous surface is built on the ground between needles, twigs, and turf/earth. It has a hardly developed valve-like exit, and the pupa is not fixed with its cremaster inside. The pupa is of reddish brown colour with darker intersegmental zones.

The first specimen, a ♂, hatched after only 3 weeks, on 7. VII. 2003.

Rearing data

Rearing material resulted from a wild collected ♀ which came to light in early v. 2003 in Shuizhou, Dagongshan, Hubei province, China, around 31°40′ N, 113°10′ E, at around 1600 m altitude. It was collected by YIN et al. Eggs were deposited in China within few days and posted by EMS letter on 9. v. 2003, they arrived in Berlin 15. v. 2003, and first larvae hatched from 17. v. 2003 on for some days, every day from around 12.00 h until early afternoon.

Larvae fixed themselves on the substrate for moulting and changed their instars at the data provided in Table 1 (data for first larva given).

Table 1: Developmental data from the rearing.

	Duration of instar [days]	Date fixed to the substrate	Date hatching/ moulting	Length after hatching/ moulting
L_1	5	21. v. 2003	23. v. 2003	5.5–6.0 mm
L_2	4	26. v. 2003	28. v. 2003	9.0 mm
L_3	4	31. v. 2003	1. VI. 2003	14.0 mm
L_4	4	4. VI. 2003	5. VI. 2003	18.0 mm
L_5	7			26.0 mm

The full grown larva had a length of about 60 mm before the cocoon was built between old needles and turf on the ground. The first cocoon was produced on 11. VI. 2003, the first pupa was seen a few days later.

Cocoons were kept at normal room temperatures (around 20°C), and no diapause resulted; moths started hatching from 7. VII. 2003 until about 16. VII. 2003. ♂♂ hatched between 2:00 and 4:00 h, ♀♀ between 4:00 and 6:00 h. Flight activity was observed, for the ♂♂, after 0:00 h, for the ♀♀, after 23:30 h for a short while. A ♂ of 8. VII. 2003 was placed together with a fresh ♀ of 9. VII. 2003 into a flight cage, stored under an open window, and a mating took place just after midnight (Fig. 21); in the morning the moths had already separated agin. The ♀ started depositing single ova fixed to needles on 10. VII. 2003 until 16. VII. 2003, when it died. It produced 96 ova in total of which some were sent to Ric PEIGLER, San Antonio, USA, who tested several other larval foodplants for this species. The resulting second generation produced again moths in the same year which then were not reared for further generations. MELL (1950: 44) reported two regular generations and a partial third one in southern areas for *A. dubernardi,* which is well confirmed herewith.

Observations

The larva of *A. dubernardi* shows some interesting peculiarities from third instar onward which in 2003 were not known for the genus *Actias* at all.

These are, first, the large silver spots on the bases of the scoli which reflect lights and give, in combination with the white granules overall on the cuticula, some kind of camouflage (compare ROUGERIE 2005b: 299). This combination is found also in the pine-feeding larvae of *A. chapae* (MELL, 1950) (compare WU & NAUMANN 2006, in this issue), but as well in other Saturniidae larvae of different subfamilies and from different continents, e.g. in the American *Syssphinx montana* (PACKARD, 1905) (Ceratocampinae) or the African *Aurivillius aratus* (WESTWOOD, 1849) (Saturniinae: Bunaeini) (pers. obs.). All those species feed on either Fabaceae which mostly have very small feathered leaves, or on Pinaceae. Shining colour probably results by light refraction from air inclusion below the cuticula, and causes mimetic effects.

A second interesting detail is the aposematic colourful warning ring between second and third thoracic segment which is enhanced by the larva by pulling down the head when disturbed. Potential predators will get frightened by this combination of intensive red, black and white colour. Such intersegmental warning stripes are known less dominantly and differently developed from a few other larvae in the genus *Actias* such as *A. isabellae* (GRAËLLS, 1849) and *A. groenendaeli* ROEPKE, 1954 (compare PAUKSTADT & PAUKSTADT 1993), but again, also from only distantly related Saturniidae taxa such as the pine-feeding North American *Citheronia sepulcralis* GROTE & ROBINSON, 1865 (compare Fig. 17). From position and development of the stripe in different *Actias* larvae it becomes clear that this is something like a parallel development. While it is situated on dorsal side between 2nd and 3rd thoracic segement and less developed between 3rd thoracic and 1st abdominal segment in *A. dubernardi,* it can be found in *A. groenendaeli* on the posterior portion of the 1st abdominal segment and in *A. isabellae* in different position laterally.

In addition to presenting the alarming stripe, the larva produces sound with its mandibles in the last two instars when disturbed. This is also known for the larvae of *A. maenas* DOUBLEDAY, 1847 and the Sulawesian endemic *A. isis* (SONTHONNAX, 1899) (compare NAUMANN 1995: 42).

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Discussion

When the ova arrived from China, the only foodplant known so far from literature was *Pinus massoniana* Lamb., mentioned by Mell (1950: 53). In recent Chinese literature on Saturniidae (Guo et al. 1989, Zhu & Wang 1983, 1993, 1996) no notes about foodplants of *A. dubernardi* were given, those plants mentioned by Wang (1992) ("*Salix matsudana, Populus* sp., *Betula* sp., *Malus pumila, Pyrus* sp., *Juglans regia, Quercus* sp.") obviously are somewhat tentatively and probably became mixed with those of other species. Finally, different coniferous plants and leaves of few *Actias*-typical deciduous foodplants were tried as potential food in Berlin: *Pinus nigra* Arnold, *P. sylvestris* L., *Larix decidua* Mill., *Abies alba* Mill., *Rhododendron* sp., *Liquidambar styraciflua* L., *Juglans regia* L., and, because widely available in its natural biotope, a bamboo species. Already in the evening of the hatching day almost all larvae were nibbling on the tips of the *Larix* needles, only few needles of *Pinus* were tested, and all other plants were refused. The complete first generation was reared on *Larix,* and only in the second generation further plants were tried, partly with the help of Richard S. Peigler in Texas who had further plants available.

Second generation larvae were reared in Berlin, after starting in first two instars with *Larix,* successfully on *Pinus sylvestris,* but did even harder than those completely fed with *Larix*. In Texas, Peigler reared the second generation larvae first on *Pinus eldarica* Medw. ("Afghan pine") and then changed to *Cedrus deodara* G. Don as food, which is native to the Himalaya. Another plant which was tried by 5th instar larva in viii. 2003 in Texas was the central Chinese relic *Metasequoia glyptostroboides* Hu & Cheng. According to Nässig (1991: 139) and Ylla (1997: 133), *A. isabellae* (in the latter publication cited with misspelling "*isabelae*"; overview about older literature see Testout 1938, comments see e.g. Nässig 1991: 133 and Renner et al. 2006: last paragraph) was reared successfully also on *Larix* and on *Cedrus,* aside of different *Pinus* species, but so far rejected species of *Taxus* (Taxaceae) as well as *Thuja* and *Juniperus* (Cupressaceae). Philipps & Rix (2002) show that *Cedrus* and *Larix* are phylogenetically more closely related to *Pinus* than to the other Pinaceae.

There are few other pine-feeding species in the genus *Actias:* The well-known western palaearctic *A. isabellae,* but also *A. chapae* (Mell, 1950) (compare Wu & Naumann 2006, in this issue) and a group of less known species around *A. felicis* (Oberthür, 1896), *A. kongjiaria* Zhu & Wang, 1993, and *A. neidhoeferi* Ong & Yu, 1968, all from China, Taiwan, and Myanmar, which will be revised shortly by Naumann et al. It is not known whether *A. dubernardi* larvae also feed on *Larix* in their natural habitat. The only Saturniid species in the subfamily Saturniinae, but different tribe Attacini, which is known to feed on *Larix* in nature is the nearctic *Hyalophora columbia* (S. I. Smith, 1865) from Canada and northern United States (Ferguson 1972: 252). It is interesting to note that there are few North American pine feeding species in the Ceratocampine genera *Citheronia* Hübner 1819 ("1816") and *Eacles* Hübner 1819 ("1816") in which larvae mainly are confined to resiniferous deciduous plants such as *Liquidambar* and Anacardiaceae, a possible parallel development. As indicated by Peigler (1986: 48) the shift of certain northern species to gymnosperms like *Pinus* or *Larix* was probably the response to a "freeze-out" of other possible foodplants during the pleistocene period. An overview about the predilection of Saturniidae larvae to resiniferous foodplants was given, e.g., by Peigler (1986) or Passoa (1998).

In recent years many hybridisation experiments took place, mostly conducted by a group of French lepidopterists (including D. Adès and R. Vuattoux) who hybridized *A. isabellae* with *A. luna* (Linnaeus, 1758), *A. sinensis* (Walker, 1855), *A. isis* and other species (compare Adès et al. 2005 and references therein) and even crossed those hybrids back to the parent species sometimes with success (Adès & Vuattoux 2005). Larvae of a hybrid stock *A. isabellae* × *A. dubernardi* showed intermediate characters of both species, with only black lateral warning stripes, and also the resulting imagos shared intermediate colour and pattern (R. Lemaître, pers. comm.). Recently, *A. sinensis* was hybridized also with *A. dubernardi* (Renner et al. 2006, in this fascicle).

Ylla et al. (2005) published a cladistic analysis of the moon moths in general. Their results and interpretations of the shown cladograms are somewhat subjective, as already pointed out in their paper: the genus *Graellsia* Grote, 1896 was separated by them again from *Actias* with the argument that by inclusion of *isabellae* in *Actias* the genus would become paraphyletic, due to differences of *Actias* with the African *Argema*. However, this argument can be quoted as well for a vice-versa viewpoint: *Actias* would as well become monophyletic if both *Argema* and *Graellsia* would be enclosed. Although rejected by Ylla et al., the hybridization experiment with even a second generation offspring resulting indicates some evidence for inclusion of *isabellae* into *Actias*. *A. dubernardi* was mentioned in the cladogram showing strict consensus of six most parsimonous trees on the same level as *A. rhodopneuma* and *A. groenendaeli*.

Almost the same results were published by Regier et al. (2002) who found some congruence in molecular phylogeny, and by Rougerie (2005a) who presented a phylogenetic tree based on 398 informative characters of adults, preimaginal instars, and genetic sequences. In both works it was found that *A. isabellae* is closer to a monophylum containing *A. isis, A. selene* (Hübner, 1811 ["1806–1823"]), and *A. luna,* than to *Argema*. This view was also published in his very informative and comprehensive thesis by Rougerie (2005b); he found three main groups in the Asian *Actias* (related to *maenas, selene,* and *sinensis,* respectively) and further some species which could not be grouped within those: *A. dubernardi,*

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A. rhodopneuma, A. chapae, and *A. felicis* (which in part may be caused by lacking information due to lacking material during the time of preparation of his work).

Nevertheless, although all of those authors placed *isabellae* and the African species into separate genera, they presented no new, substantial reasons aside of subjective and traditional treatment to handle it that way. When looking at similarities, e.g., in the ♂ genitalia structures of *A. sinensis* and *A. rhodopneuma* or *A. dubernardi, A. chapae* and *Argema* species, combined with the above subjective interpretations, it could not be totally disregarded to think even about the logical "neccessity" of reinstating genera like *Euandrea* (for *dubernardi,* as mentioned by Testout 1944, and *chapae*) and *Sonthonnaxia* (the latter sometimes used in subgeneric level or, without taxonomic rank, to classify a group of species around *A. maenas*). Taking all the similarities of the Asian, African, European and American species into consideration, it becomes more plausible to have one large genus *Actias* almost occuring worldwide with *Graellsia* and *Argema* included, which then would as well be a monophylum again.

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Plate 2: *Citheronia sepulcralis* and *Actias dubernardi*. **Fig. 17:** *Citheronia sepulcralis,* larva in L_4 (penultimate instar). — **Figs. 18–23:** *A. dubernardi.* **Fig. 18:** ♂ and ♀ cocoon. **Fig. 19:** ♂ and ♀ pupa in opened cocoons. **Fig. 20:** Live ♂, ventral view. **Fig. 21:** Mating pair in flight cage. **Fig. 22:** Live ♀, dorsal view. **Fig. 23:** ♂ genitalia, no. 940/03 Naumann, from Guizhou specimen. — Photographs author.

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